Interpretation of InSAR Mapping for Geometrical Structures

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Abstract—**In this paper we present a methodology to detect large geometrical structures from Interferometric Synthetic Aperture Radar (InSAR) measurements. The ortho-rectification of Synthetic Aperture Radar imagery which is a part of Interferometric SAR processing can be a many-pixels to one-pixel mapping. This mapping is used for automatic detection of geometrical structures which are large compared to the SAR resolution.**

Index Terms—**InSAR Processing, Electromagnetic Scattering, Radar Mapping, Geometrical Structure.**

I. Introduction

Interferometric Synthetic Aperture Radar (InSAR) provides the capability to measure surface topography and radar reflectance with moderate resolution. A description of InSAR data acquisition and processing is in [1]. Airborne InSAR imaging systems operate at a number of frequency bands such as P, L, C, and X. Recently, the space shuttle radar topography mission (SRTM) collected InSAR data at C and X bands.

Image processing steps to produce the surface topography and radar reflectance image are well known. First, synthetic aperture radar (SAR) images are formed by range and azimuth compression of the collected radar data. Next, interferometric phase is derived by co-registering SAR images. Phase unwrapping is then used to relate the interferometric phase to the distance between the radar platform and the ground surface. Finally, surface topography is derived using the unwrapped interferometric phase and the imaging geometry of the radar platform. This step produces ortho-rectified SAR intensity and topography maps. A topography map is represented in terms of (x, y, z) coordinates with respect to a reference coordinate system. For a given pixel, the vertical dimension, z, is the measured elevation. The imaging geometry parameters are the platform altitude and the interferometric baseline. This last step in InSAR processing is a mapping of SAR data from radar coordinates to ground coordinates.

In this paper we focus on the mapping of the SAR image and the associated topography data from the radar coordinates to ground coordinates. Fig. 1 shows both the radar-range coordinate and the ground-range coordinate. The elevation coordinate is also shown. Letters (A, B, C) and (A', B', C') which are shown in this figure illustrate the relationship between the radar-range and the ground-range coordinates. Typically this mapping is one to one, as is shown in this figure. That is, one pixel of the SAR image in the radar coordinate system is mapped to one pixel of the SAR image in the ground coordinate system, for example (B, B'). However, it is possible that many data points in the radar coordinate system are mapped to one point on the ground coordinate system, as will be shown in Fig. 2. These locations correspond to geometrical structures which are large compared to the SAR resolution. We demonstrate this property using measured C-band, 40 MHz InSAR data which is collected over Los Angeles.

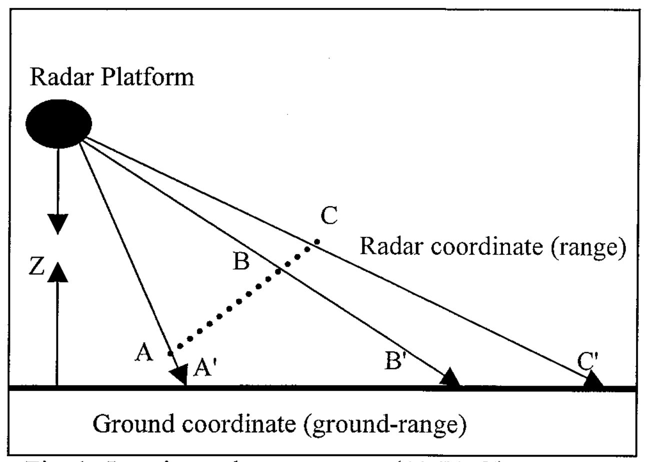

Fig. 1. Imaging radar geometry. (A', B', C') are on ground-range coordinate. (A, B, C) are on the radar-range coordinate. Topography is measures along the z-axis. Radar view angle to a given pixel on the ground-range coordinate is computed from the interferometric phase.

II. Theoretical Overview

Interpretation of InSAR imagery and the associated topography is complicated for regions where geometrical structures are present. Fig. 2 shows a geometry where multiple regions, (A, A'), (B, B') have the same range values with respect to the radar platform. The reconstructed topography from InSAR measurement for this geometry might not be correct and is dependent on the electromagnetic scattering behavior of regions (A, A'), and (B, B').

In order to illustrate the complications due to the presence of the geometrical structure in Fig. 2, we compare the SAR

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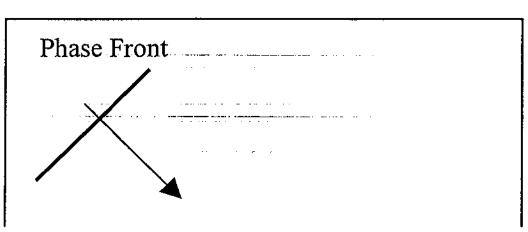
intensity image for figures 1 and 2. In Fig. 1, regions (A', B', C') are mapped onto (A, B, C) in the radar-range coordinate. In Fig. 2, Regions (A, A') are mapped to the same pixel in the radar-range coordinate. The same effect occurs for regions (B, B'). If A is a strong electromagnetic scatterer in comparison with A', the intensity image of region A appears before the pixel corresponding to region B' in the SAR image. This is called the layover effect which distorts the SAR intensity image. A detailed discussion of the layover effects for SAR imagery due to topography is in [2].

InSAR measurements contain both the SAR intensity and the interferometric phase. The interferometric phase is used to compute the radar view angle from the radar platform to a pixel on the ground-range coordinate. In Fig. 1 for example, the radar view angle for region B' is the angle between the negative z-axis, and BB' vector. The elevation corresponding to B' is derived using the range and the view angle values. In Fig. 2, the view angle for the pixel corresponding to A and A' (both have the same range value), can either correspond to region A, A', or a weighted average depending on the relative backscattering strength of regions A and A'. The corresponding elevation, therefore, might not be correct. This interpretation assumes that phase unwrapping is successful in areas where the layover effect is dominant.

The ortho-rectifed map contains pixels where no data is mapped onto them. These pixels can correspond to areas in the shadow of dominant topographical features, or areas where the interferometric phase is unreliable and the corresponding phase unwrapping is not successful. It is interesting to note that there are pixels where more than one interferometric data are mapped on to them. This corresponds to multiple elevation data at the same position on the ground coordinates. This effect corresponds to geometrical structures with elevations that correspond to multiple range values, and their scattering behavior is dominate with respect to other areas with the same range values. Fig. 2 illustrates the situation where multiple elevations are mapped into the same range pixel in ground coordinates. In this figure we assume that the locations A and B are dominant scattering centers. Locations A' and B' are at the same range as A and B, respectively. In radar range coordinates, points (A, A') overlap. Similarly, B and B' overlap in the SAR image.

The ortho-rectification process which is the mapping of the SAR data from the radar coordinates to the ground coordinates locate the elevation values corresponding to A and B since they provide the dominant (or strong) scattering towards the radar platform. We use this property to locate a geometrical structures in InSAR measurements.



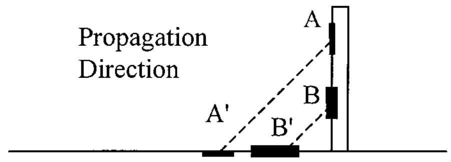


Fig. 2. Description of the layover effect for geometrical structures. Direction of the radar signal propagation is denoted by the arrow on the upper left hand corner. Areas A, and A' have the same range value with the respect to the radar platform. Similarly, B and B' have the same range value. On the radar-range coordinate, A might appear before B' if A is a dominant scatterer in comparison to A'.

III. Application

Based on the description of the characteristics of the ortho-rectification mapping, it is possible to extract the location of geometrical structures from the InSAR data automatically. This automatic detection consists of keeping track of the number of data points at each pixel in the ground coordinates. Multiple data points at a pixel can correspond to the presence of a geometrical structure as illustrated in Fig. 2. This approach complements the methodology described in [3] and [4] to extract large structures in the urban environment.

This detection scheme is applied to the InSAR data collected over Los Angeles, CA. The area of interest contains large building structures which fit the characteristics of the geometry described in Fig. 2. Electromagnetic scattering from buildings are dominate in comparison with scattering from open fields and vegetation due to the presence of corner reflectors. We expect in this area the pixels which contain multiple data to correspond to large building structures. Fig. 3 is an optical image of the area of interest. The bright white areas in this image generally correspond to rooftops of buildings with large footprints. Open parks and residential areas are present in this image as well. Fig. 4 is the SAR intensity map of a slightly larger area. The area which is shown in Fig. 3 is located at the center of this image. The SAR data is ortho-rectified. This data is acquired by the JPL airborne C-band interferometric SAR system. The system bandwidth is 40 MHz. The ground pixel size is 5 meters and the data resolution is approximately 10 meters.

We apply our methodology to the InSAR data for this region. The blue (square) dots on this figure correspond to the detected pixels where there are multiple data points per pixel. These blue marks correspond to large building structures in this urban area. The red (diamond) marks in this figure correspond to the location of a number of tall structures in the same region. We use this data as the ground truth. There is good correlation between the detected structures and the location of tall (more than 40 meters) buildings.

Fig. 3. Optical Image of a portion of Los Angeles, CA. Tall geometrical structures are shown in white color.

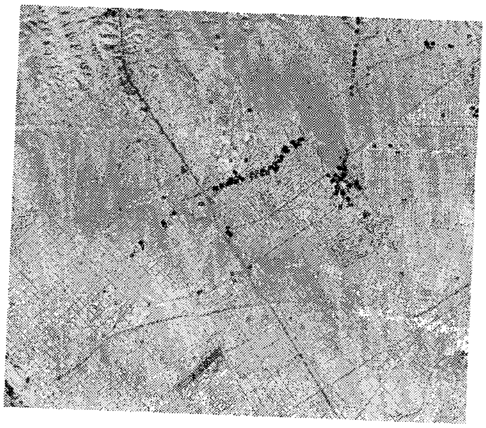


Fig. 4. SAR image of the West side of Los Angeles, CA. Location of tall structures are detected automatically using the number of elevation values per pixel. Square marks show the detected structures.

IV. Conclusion

Geometrical structures are detected from the InSAR data by taking into account the number of data points per pixel in the ground-range coordinate. This information is available as part of the mapping of the SAR data from radar coordinates to ground coordinates. We apply our methodology to C-band, 40 MHz InSAR data collected over Los Angeles, CA. We are able to detect large structures. This detection capability is consistent with our assumptions shown in Fig. 2. Based on this model, we observe that higher resolution InSAR measurements improve this detection capability.

Acknowledgment

The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

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